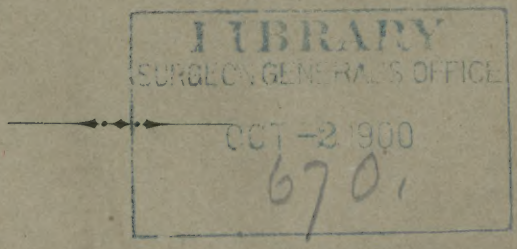
HUXLEY AND HIS WORK.

BY

THEODORE GILL.

FROM THE SMITHSONIAN REPORT FOR 1895, PAGES 759-779
(WITH PLATE LXXIV).



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I.

The history of scientific progress has been marked by a few periods of intellectual fermentation when great bounds have been taken forward and a complete revolution ensued. Very few have been such, but in one the name of Huxley must be ever conspicuous. It was as a lieutenant of the organizer of that revolution that he appeared, but unquestionably without him it would have been long delayed, and it was through his brilliant powers of exposition that the peoples of the English-speaking lineage soon learned to understand, to some extent, what evolution was and, learning, to accept it.

On the 4th of May, 1825, was born the infant Huxley, in due course christened Thomas Henry. "It was," Huxley himself has remarked, "a curious chance that my parents should have fixed for my usual denomination upon the name of that particular apostle with whom I have always felt most sympathy." In his physical and mental peculiarities, he was completely the "son of his mother," whose most distinguishing characteristic was "rapidity of thought;" that characteristic Huxley claimed to have been passed on to him "in full strength," and to have often "stood him in good stead," and to it he was undoubtedly indebted for success in the many intellectual duels he was destined to be engaged in. His "regular school training was of the briefest," and he has expressed a very poor opinion of it. His early inclination was to be a mechanical engineer, but he was put to a brother-in-law to study medicine. The only part of his professional course which really interested him was physiology, which he has defined as "the mechanical engineering of living machines." The only instruction from which he thought he ever obtained the proper effect of education was that received from Mr. Wharton Jones, who was the lecturer on physiology at the Charing Cross School of Medicine. At Mr. Jones's suggestion, in 1845, Huxley communicated to the Medical Gazette (p. 1340) his first

[1] A memorial address given on January 14, 1896, before the scientific societies of Washington. Reprinted, with additions, from Science, February 21, 1896. New series, Vol. III, No. 60.

paper "On a hitherto undescribed structure in the human hair sheath." Two years later he contributed to the British Association for the Advancement of Science the first paper generally attributed to him, "Examination of the corpuscles of the blood of Amphioxus." (Abstracts, p. 95.) In 1845 he passed the first M. B. examination at the London University. Soon afterwards he was admitted into the medical service of the navy and was, after some waiting, assigned to the *Rattlesnake*, and for four years (1846–1850) served on her during her exploration of the Australasian seas; he was, he supposed, among the last voyagers "to whom it could be possible to meet with people who knew nothing of firearms—as [they] did on the south coast of New Guinea."

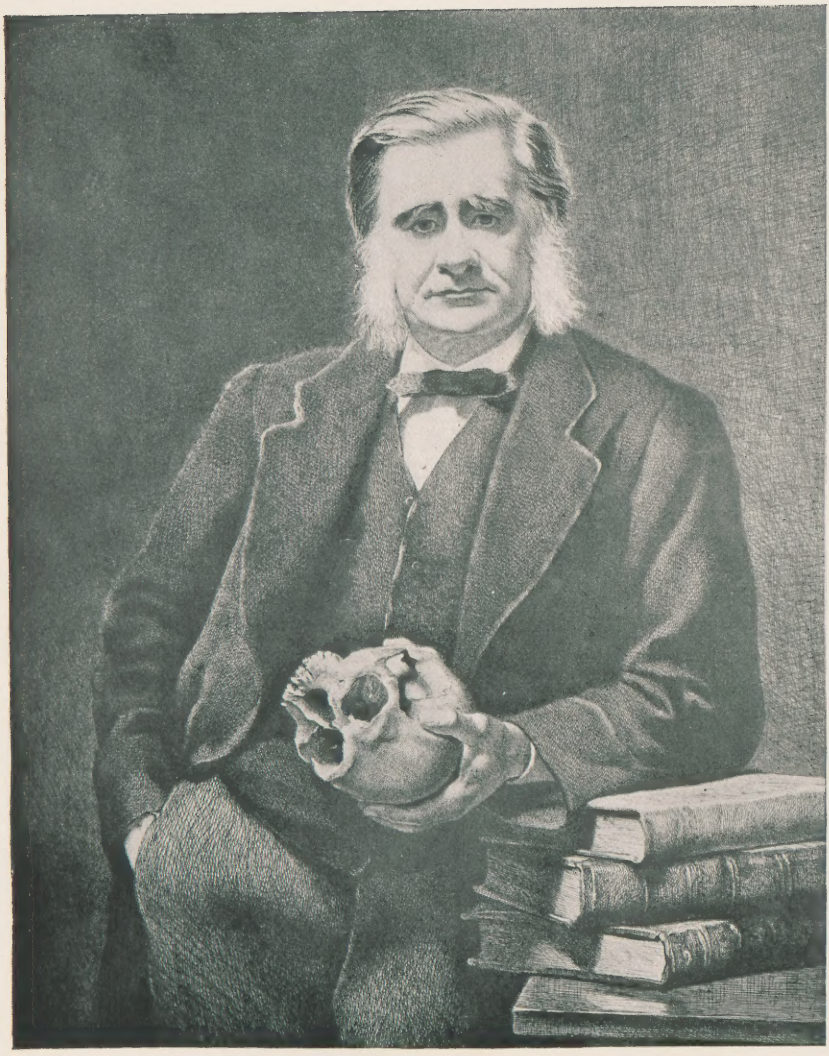
While on board Huxley zealously prosecuted zoological investigations, and in 1849 and 1850 sent records of various observations, in papers which were published in the Philosophical Transactions and Annals and Magazine of Natural History. Most important of all was a monograph on the Oceanic Hydrozoa, published by the Ray Society. It is amusing to find that while in Sydney he was impressed by MacLeay and lead to believe that "there is a great law hidden in the 'Circular system' if we could but get at it, perhaps in Quinarianism, too,"[1] but sober sense doubtless soon came to the rescue and he appears to have been never otherwise touched by the strange monomania that had been epidemic in England during the previous quarter century. In 1851 he became a F. R. S. He continued in the navy three years after his return, but in 1853 resigned when ordered to sea again.

In 1853 Huxley and Tyndall became candidates for professorships in the University of Toronto, but that university preferred others for the vacant places and thus missed the opportunity of an age. In 1854 Huxley was appointed to the post of lecturer on natural history in the School of Mines, which he held for the next thirty-one years. In the same year he became Fullerian professor in the Royal Institution. "The first important audience [he] ever addressed was at the Royal Institution." In 1862 he served as president of the biological section, and in 1870 of the British Association for the Advancement of Science itself; in 1869 and 1870 of the Geological and Ethnological Societies, and in 1883 to 1885 of the Royal Society. He was inspector of salmon fisheries from 1881 to 1885.

In 1876 he visited the United States and delivered an address at the opening of the Johns Hopkins University.

In 1885 failing health and desire for freedom led him to retire from most of his offices, and thenceforth he devoted himself chiefly to literary work rather than to scientific investigation. On the accession of Lord Salisbury to the premiership in 1892, Huxley was made privy counselor, and with it came the title of Right Honorable, by which he was later styled. In the last years of life he resided at Hodeslea, Eastbourne, and

[1] Ann. Mag. Nat. Hist. (2), VI, page 67.



THOMAS HENRY HUXLEY. (1825-1895.)
(From etching by Flameng after painting by Collier.)

after a long illness ("complication following influenza"[1]) died there on the 29th of June, 1895.

Such were the principal episodes in the life of Huxley. Many more details may be found in the numerous periodicals of the day, and in some of them are depicted various phases of his character and labors. The short time that is at our disposal to-night may be most profitably and entertainingly utilized in reviewing his feats as a warrior of science and estimating the measure of influence he exercised in diverting human thought from the ruts in which it had moved for centuries and directing it into a highway where increasing light from different sides could guide the wayfarer. Although this period of warfare was at its height not further back than the early afternoon of the present century, and some of us here assembled joined in the fray, to the younger naturalists it is an unknown past except through history, and to some of us who were of it, it is so strange as to recur to us rather as a dream than as a realized passage in actual life.

II.

Doubtless man, almost from the moment of his acquisition of those characters which distinguish him as representative of the genus Homo, had wondered and speculated as to how he came into being and how the animals assembled round him had sprung into existence. Those early concepts must have been strange, indeed, but were doubtless transmitted from mother to child, only with some eccentricities lopped off with advancing intelligence. Gradually, among peoples of the Aryan stock at least, they crystallized into a doctrine that in the beginning there was chaos, that the three elements of air, water, and earth were differentiated, and that animals were successively created to occupy the spaces. Such were the views of the old oriental cosmologists and such of the later Romans as epitomized in Ovid's verse. These ideas were long regnant and naturalists embodied some in their schemes, most accepting the idea that animals may have been created in pairs, but a few (such as Agassiz) urging that they must have been created in communities approximating to those still found. There were very few to dissent from these views of specific creation, and those few had little influence on the popular beliefs. But as the present century advanced, curious men delved into all the mysteries of nature; the sciences of morphology, physiology, histology, embryology, geology, and zoogeography came into being, and facts were marshaled from every side that militated against the old conceptions. Even when these sciences were inchoate, or new born, sagacious men had perceived the drift of the facts and anticipated induction by the formulation of hypotheses of evolution, but the hypotheses were too crude to insure acceptance. Meanwhile, however, the facts accumulated, and in 1859 a factor determining the

[1] Lancet, July 6, pp. 64, 65.

course of development of species was appreciated by Darwin and Wallace, and soon applied to a wide range of facts in the former's Origin of Species by means of Natural Selection.

Darwin's work at once aroused great popular interest, but it was too diffuse and the intellectual pabulum it contained was too strong and indigestible for ordinary readers, and it is probable that the general acceptance of the Darwinian form of evolution would have been delayed much longer than it was had it not been for the excursions from the scientific fold into the popular arena by one having the confidence of the former and the ear of the latter, as did Huxley.

Scarcely had Darwin's work come from the press when Huxley commenced his missionary work. Almost exceptional among numerous reviews, remarkable chiefly for crudity, ignorance, and arrogance, was one that appeared in the great daily organ of English opinion, The Times, marked by superior knowledge, acuteness of argumentation, and terse and vigorous style. This review, which attracted general attention, was acknowledged later by Huxley. Lectures and addresses before popular audiences, and even to those distinctively claiming to be "workingmen," followed, and these were published or supplemented by publication in various forms. Answers, critiques, and other articles in reply came out in rapid succession, and loud clamor was made that Huxley was an infidel and a very bad man, and that he falsified and misrepresented in a most villainous manner.

A memorable occasion was the meeting of the British Association for the Advancement of Science in the year 1860, following the publication of the Origin of Species. A discussion of the subject was precipitated by the presentation of a communication by our own Draper, "On the intellectual development of Europe with reference to the views of Mr. Darwin and others that the progression of organisms is determined by law." The reverend Mr Cresswell and the reverend Dr Wilberforce, Bishop of Oxford, followed in opposition, and they were answered by Huxley. The scene has lately been redescribed by a great physiologist and friend of Huxley, who is one of the few witnesses who now remain. "The room was crowded, though it was Saturday, and the meeting was excited. The bishop had spoken; cheered loudly from time to time during his speech, he sat down amid rapturous applause, ladies waving their handkerchiefs with great enthusiasm; and in almost dead silence, broken merely by greetings which, coming only from the few who knew, seemed as nothing, Huxley, then well-nigh unknown outside the narrow circle of scientific workers, began his reply. A cheer, chiefly from a knot of young men in the audience, hearty but seeming scant through the fewness of those who gave it, and almost angrily resented by some, welcomed the first point made. Then as, slowly and measuredly at first, more quickly and with more vigor later, stroke followed stroke, the circle of cheers grew wider and yet wider, until the speaker's last words were crowned with an applause falling not far short of, indeed

equaling that which had gone before, an applause hearty and genuine in its recognition that a strong man had arisen among the biologists of England."

The versatile bishop indulged in the argumentum ad hominem so very trite and familiar to us all (who has not heard it?) he would like "to hear from Mr. Huxley whether it was by his grandfather's or grandmother's side that he was related to an ape."

Huxley replied and answered: "I asserted, and I repeat, that a man would have no reason to be ashamed of having an ape for a grandfather. If there were an ancestor whom I should feel shame in recalling it would be a man; a man of restless and versatile intellect who, not content with an equivocal success in his own sphere of activity, plunges into scientific questions with which he has no real acquaintance, only to obscure them by an aimless rhetoric and distract the attention of his hearers from the real point at issue by eloquent digressions and skilled appeals to religious prejudice."

The arguments adduced against evolution during those days were sometimes very comical, and the confident air of the upholder of the ancient views and the assurance with which he claimed that his position was fixed and that the burden of proof rested entirely upon the advocate of the opposite view were very amusing. It was urged that no one had ever seen one species turn into another. Had anyone ever seen any animal made? Could anyone really conceive of any animal being actually made? Did an omnipotent Creator actually take the "dust of the ground" and mold it into animal shape and then breathe into its nostrils "the breath of life?" "Did infinitesimal atoms flash into living tissues?" Certainly no physiologist with a competent knowledge of histology could believe in any such mode of creation. On the other hand, everyone that could exercise the necessary skill could follow the evolution of an animal from an undifferentiated protoplasmic mass into a perfect animal. A clutch of eggs could be successively taken from a mother hen or a hatching oven, and day after day the actual evolution of the undifferentiated matter into derivative functional parts could be followed. That which is true of the hen is true of man, only in the latter case it is more difficult to obtain the requisite material and greater skill to use it is requisite. Compare the embryos developing in the hen and human eggs and at first no difference except size and environment can be perceived. Compare them in successive stages, and adult animals more or less parallel to some early stages may be found still living or entombed in earlier formations of the earth in fossilized form.

It was argued that no one had ever seen one species turn into another. But is it not a matter of historical evidence that many breeds of domestic animals have actually been developed by the agency of man and propagate their kind? And how are such breeds distinguished from species except by the fact that we know their origin, and

that they have come into prominence through selection by man rather than by nature? Interbreeding is no criterion.

But it is unnecessary to go into details, and these hints are offered only because their bearings on the subject were so generally overlooked by those who opposed evolution. One opponent, so eminent as to be styled the "pope" of a great Protestant Church, published a work against evolution largely based on the contention that the existence of the eye, except through direct creation, was inconceivable. Yet this very evolution of the eye from simple protoplasm could have been witnessed at any time with little trouble in the hen's egg. Is evolution through great reaches of time more inconceivable than actual evolution capable of daily observation?

Well and skillfully did Huxley meet the arguments against evolution. Even most of the old naturalists sooner or later recognized the force of the arguments for and the weakness of those against evolution. Those who did not in time gave up the contest with their lives. The young who later entered into the field of investigation have done so as evolutionists.

It is interesting to recall that the illustrious American (Professor Dana) who recently departed so full of years and honors, and of whom you have heard from a former speaker (Major Powell) to-night at length, in the full maturity of his intellect, accepted unconditionally the doctrine of evolution and dexterously applied it in his last great work.

III.

Darwin, in his Origin of Species, had refrained from direct allusion to man in connection with evolution and many casual readers were doubtless left in uncertainty as to his ideas on the subject. Naturally, the scientific man recognized that the origin of his kind from a primate stock followed, and believed that Darwin's reticence was probably due to a desire to disturb popular beliefs as little as possible. When we recall what strange views were held respecting man's origin and relations we can understand how the unlearned could easily fail to recognize that man must follow in the chain of his fellow-creatures. (We preserve creature still as a reminiscence of ancient belief, but without the primitive conception attached to the word.)

Man was claimed as a being isolated from animals generally, and naturalists of acknowledged reputation and one or two of great fame more or less completely differentiated him from the rest of the animal kingdom and even from the animal kingdom itself.

As long as the isolation of man from the animal kingdom, or from the greater part, was based on metaphysical or psychological ideas, the naturalist perhaps had no cause of quarrel, although he might wonder why a morphologist should stray so far from the field of observation. But when naturalists confused morphological and psycholog-

ical data, he had reason to protest. This confusion was effected by one of great eminence. There was no naturalist in Britain about the middle of the century who enjoyed a reputation equal to that of Richard Owen. An anatomist of preeminent skill and extraordinary industry, his merits had been appreciated by the entire world. An opinion of his had a weight accorded to no others. Consequently a new classification of the mammals, published by him in 1857, soon became popular. This classification was founded on alleged characters of the brain and on successive phases of increase in the cerebrum. Man was isolated not only as the representative of a family, but of an order and a subclass.

According to Owen, "in man the brain presents an ascensive step in development, higher and more strongly marked than that by which the preceding subclass was distinguished from the one below it. Not only do the cerebral hemispheres overlap the olfactory lobes and cerebellum, but they extend in advance of the one and farther back than the other. Their posterior development is so marked that anatomists have assigned to that part the character of a third lobe. It is peculiar to the genus Homo, and equally peculiar is the 'posterior horn of the lateral ventricle,' and the 'hippocampus minor,' which characterize the hind lobe of each hemisphere. The superficial gray matter of the cerebrum, through the number and depth of the convolutions, attains its maximum of extent in man. Peculiar mental powers are associated with this highest form of brain, and their consequences wonderfully illustrate the value of the cerebral character."

The views thus expressed by Owen were reiterated on various occasions, but many anatomists dissented from them, and the rumbling of a future storm was betokened. At last the storm cloud broke, and Owen was overwhelmed. At a great popular assemblage at Oxford, on the occasion of the meeting of the British Association for the Advancement of Science, Owen once more urged his contention of the cerebral characteristics of man, and maintained this wide difference from the apes.

Huxley immediately rose and, with that cogency of reasoning which characterized him, proceeded to divest the subject of the sophistries in which it had been enveloped. "The question," he said, "appeared to him in no way to represent the real nature of the problem under discussion. He would therefore put that problem in another way. The question was partly one of facts and partly one of reasoning. The question of facts was, What are the structural differences between man and the highest apes?—the question of reasoning, What is the systematic value of those differences? Several years ago Professor Owen had made three distinct assertions respecting the differences which obtained between the brain of man and that of the highest apes. He asserted that three structures were 'peculiar to and characteristic' of man's brain, these being the 'posterior lobe,' the 'posterior cornu,' and the 'hippocampus minor.' In a controversy which

had lasted for some years Professor Owen had not qualified these assertions, but had repeatedly reiterated them. He (Professor Huxley), on the other hand, had controverted these statements; and affirmed, on the contrary, that the three structures mentioned not only exist, but are often better developed than in man, in all the higher apes. He (Professor Huxley) now appealed to the anatomists present in the section whether the universal voice of Continental and British anatomists had not entirely borne out his statements and refuted those of Professor Owen. Professor Huxley discussed the relations of the foot of man with those of the apes, and showed that the same argument could be based upon them as on the brain; that argument being that the structural differences between man and the highest ape are of the same order, and only slightly different in degree from those which separate the apes one from another. In conclusion, he expressed his opinion of the futility of discussions like the present. In his opinion the differences between man and the lower animals are not to be expressed by his toes or his brain, but are moral and intellectual."

The appeal to anatomists was answered on the spot. The foremost anatomists of England there present (Rolleston and Flower) successively rose and indorsed the affirmations of Huxley. Not one supported Owen, and, brilliant as his attainments were, his want of candor entailed on him the loss of his eminent place, and Huxley took the vacated throne. But the contest that resulted in Owen's overthrow was of great service, for in the chief centers of civilization anatomists eagerly investigated the question at issue, and the consequence was that in a few years more material had been collected and studied than under ordinary conditions would have been done in five times the period. Unlike other battles, one in scientific warfare is almost always advantageous to the general cause, whatever it may be to a party.

IV.

The first important memoir by Huxley was written in his twenty-third year On the Anatomy and the Affinities of the Family of the Medusæ (Phil. Trans., 1849, pp. 413–434, pl. 37–39), and contained the germ of a fundamental generalization. He therein laid "particular stress upon the composition of [the stomach] and other organs of the medusæ out of two distinct membranes, as," he says, "I believe that is one of the essential peculiarities of their structure, and that a knowledge of the fact is of great importance in investigating their homologies. I will," he continues, "call these two membranes as such, and independently of any modification into particular organs, 'foundation membranes'" (p. 414). In his summary (p. 425) he also formulates "that a medusa consists essentially of two membranes, inclosing a variously shaped cavity, inasmuch as its various organs are so composed."

I have thus given Huxley's own words, inasmuch as Professor

Haeckel has asserted that Huxley therein "directed attention to the very important point that the body of these animals is constructed of two cell layers—of the ectoderm and endoderm—and that these, physiologically and morphologically, may be compared to the two germinal layers of the higher animals" (Nature, 1874), and Professor Kowalevsky has also claimed that Huxley "founded modern embryology by demonstrating the homology of the germinal layers of vertebrates with the ectoderm and endoderm of cœlenterates." (Nature, October 31, 1895, p. 651.)

In all candor, I must confess that, important as the generalization of Huxley for the Medusæ was, it was only applied by him to the Medusæ, and was not necessarily extensible with the homologies indicated, but it was pregnant with suggestiveness, and to that extent may have led to the wider generalization that followed. Let all possible credit then be assigned to it.

The classification of animals generally adopted, and in this country especially, up to at least the early years of the present half century, was based on what was called plan or type, and was mainly due to Cuvier. According to this school, there were four "great fundamental divisions of the animal kingdom," and these were "founded upon distinct plans of structure, cast, as it were, into distinct molds or forms." The term generally used to designate this category was branch or subkingdom, and the subkingdoms themselves were named vertebrates, mollusks, articulates, and radiates. Various modifications of this system and more subkingdoms were recognized by many zoologists, but the one specially mentioned was in very general use in the United States because favored by Agassiz, who then enjoyed a great reputation. Almost all naturalists of other countries, and many of this, recognized the distinctness, as subkingdoms or branches, of the Protozoans and cœlenterates. But Huxley, in 1876, went still further and segregated all animals primarily under two great divisions based on their intimate structure, accepting for one the old name, Protozoa, and for the other Haeckel's name, Metazoa.

"Among those animals which are lowest in the scale of organization there is a large assemblage which either present no differentiation of the protoplasm of the body into structural elements, or, if they possess one or more nuclei, or even exhibit distinct cells, these cells do not become metamorphosed into tissues—are not histogenetic. In all other animals the first stage of development is the differentiation of the vitellus into division masses, or blastomeres, which become converted into cells, and are eventually metamorphosed into the elements of the tissues. For the former the name Protozoa may be retained; the latter are coextensive with the Metazoa of Haeckel."

While not exactly original with Huxley, the recognition of these two great categories of the animal kingdom was hastened among naturalists, and found place in most of the works by men of authority that

followed. That such recognition greatly facilitates morphological concepts is certain. But most of the further new features of this classification have not received the approbation of naturalists generally.

V.—The Vertebrate Theory of the Skull.

Germany's great poet, Goethe, was "passionately devoted to the natural sciences," but was "induced by the habit of his mind to search for the general truths which give life to the dry bones of detail." In the Jewish cemetery of Venice, a broken sheep's skull came under his notice and he thought he recognized that it was made of modified vertebræ. Another German, Oken, in the Hartz mountains, "stumbled upon the blanched skull of a deer," and he was inspired with the idea that "it is a vertebral column." Oken immediately proclaimed his idea to the world. It found acceptance in many places and England's great anatomist, Richard Owen, took it up and carefully elaborated a new form of it. Owen's modifications, dubbed the "archetype" of the skeleton, became popular in Britain and America, and elements of the skull were described in terms indicating that they were "homotypes" with appendages of vertebra, the nasals, for example, being styled the neural spines of the nasal vertebra, the premaxillary the hæmal spine of the same vertebra, and the dentary of the lower jaw the hæmal spine of the frontal vertebra. But still more fanciful was the terminology for the limbs, the anterior being allocated to the occipital vertebra, and the scapula regarded as a pleuropophysis, the coracoid as a hæmapophysis, and the limb itself as a "diverging appendage."

Strange as this conception may appear to the young who have only been educated in modern methods, it had attractions for some, as I can testify from personal experience. When a boy I made an enlarged copy of the diagram republished in Carpenter's Physiology and colored the neurapophyses blue and the hæmapophyses red. Later reflection led me to the conclusion that an "archetype" should be more or less realized, and if it were not, it had no place in nature. As the Owenian archetype was at most only distantly approximated by specialized fishes, it could not be a true archetype of the vertebrate skeleton as such, however near it might represent the typical fish skeleton. Doubtless others were led by similar reasoning to discard the Owenian ideas, yet they continued in favor among many.

But in 1858, in a lecture on the Croonian foundation before the Royal Society, with Owen himself in the chair, Huxley discoursed "on the theory of the vertebral skull," and conclusively showed the inconsistency of the archetypal conception with the facts of embryology and development. After a recapitulation he confessed that he did "not perceive how it is possible, fairly and consistently, to reconcile these facts with any existing theory of the vertebrate composition of the skull, except by drawing ad libitum upon the Deus ex machinâ of the speculator—imaginary confluences, 'connations,' 'irrelative repetitions,' and shiftings of position—by whose skillful application it would not be

difficult to devise half a dozen very pretty vertebral theories, all equally true, in the course of a summer's day." He naturally reached not only "the negative conclusion that the doctrine of the vertebral composition of the skull is not proven," but "the positive belief that the relation of the skull to the spinal column is quite different from that of one part of the vertebral column to another."

The blow thus dealt against the Owenian archetype was a serious one, and it was nearly coincident with the growing adoption of the doctrine of evolution and the overthrow of the doctrine of types and patterns. At any rate, the old idea of the vertebration of the skull became an idea of the past. Owen continued to preach it, but his disciples abandoned it, and he was soon left without a single notable follower.

VI.—Classification of Ganoid Fishes.

The designation of Ganoidei was originally given by Agassiz to a heterogeneous group of fishes distinguished by a covering of what were called ganoid scales and having no other common characters; some of its representatives even lacked the "ganoid" scales. But most of the extinct species, at least, were really structurally affiliated and such were segregated by Johannes Müller in a comparatively natural group distinguished by cerebral, cardiac, and intestinal peculiarities, and for this group was retained the Agassizian term Ganoidei. Its constituents were contrasted under two subordinate groups named Chondrostei and Holostei. The families of the latter group were evidently related in various degrees, but such degrees were not expressed in the arrangement of the families, and the families themselves were mostly defined by superficial characters of little value. The appointment of Huxley to the professorship of natural history in the Government School of Mines led him to investigations which culminated in a "Preliminary Essay upon the Systematic Arrangement of the Fishes of the Devonian Epoch" (1861), and "Illustrations of the structure of the Crosstopterygian Ganoids" (1866). He proceeded "to reconsider the whole question of the classification of the fishes of this epoch, and, eventually, to arrive at results which seem to necessitate an important modification of the received arrangement of the great order of Ganoidei." He recombined the Chondrostei and Holostei, and then distributed the aggregate (which he designated as an order) into five suborders in the following manner:

Ordo GANOIDEI.[1]

Subordo I.—Amiadæ.
Subordo II.—Lepidosteidæ.
Subordo III.—Crossopterygidæ.
Fam. 1.—Polypterini.
Dorsal fin very long, multifid; scales rhomboidal.
Polypterus.

[1] Memoirs of the Geological Survey of the United Kingdom. Figures and descriptions illustrative of British Organic Remains, Decade X, pages 23, 24.

Subordo III.—CROSSOPTERYGIDÆ—Continued.
Fam. 2.—SAURODIPTERINI.
Dorsal fins two; scales rhomboidal, smooth; fins subacutely lobate.
Diplopterus, Osteolepis, Megalichthys.
Fam. 3.—GLYPTODIPTERINI.
Dorsal fins two; scales rhomboidal or cycloidal, sculptured; pectoral fins acutely lobate; dentition dendrodont.
Sub-fam. A. with rhomboidal scales.
Glyptolæmus, Glyptopomus, Gyroptychius.
Sub-fam. B. with cycloidal scales.
Holoptychius, Glyptolepis, Platygnathus [*Rhizodus, Dendrodus, Cricodus, Lamnodus*].
Fam. 4.—CTENODODIPTERINI.
Dorsal fins two; scales cycloidal; pectorals and ventrals acutely lobate; dentition ctenodont.
Dipterus [*Ceratodus? Tristichopterus?*].
Fam. 5.—PHANEROPLEURINI.
Dorsal fin single, very long, not subdivided, supported by many interspinous bones; scales thin, cycloidal; teeth conical; ventral fins very long, acutely lobate.
Phaneropleuron.
Fam. 6.—CŒLACANTHINI.
Dorsal fins two, each supported by a single interspinous bone; scales cycloidal; paired fins obtusely lobate; air bladder ossified.
Cœlacanthus, Undina, Macropoma.
Subordo IV.—CHONDROSTEIDÆ.
Subordo V.—ACANTHODIDÆ.

The chief merit in this arrangement is the appreciation of the closeness of the relations between the extinct fishes of the groups now recognized as Dipnoans and Crossopterygians, and the anticipation, by a kind of intuition, of part of the truth as now recognized. The "suborder Crossopterygidæ" of Huxley is really a compound of the subclasses or superorders of Dipnoans and Crossopterygians. The distinctive characters of the two were not recognized, and the author even failed to appreciate the exact relations of the living and extinct Dipnoans, or that, in fact, many of his Crossopterygidæ are really Dipnoans.[1] In his Anatomy of the Vertebrates (1871), even he retained his arrangement of the "Ganoidei," which were placed as the fourth order of fishes, and considered the "Dipnoi" after the Teleostei and as the sixth order of fishes. He failed even to find any extinct Dipnoans, and concluded his observations on the group with the statement that "It is a remarkable circumstance that, while the *Dipnoi* present, in so many respects, a transition between the piscine and the amphibian types of structure, the spinal column and the limbs should be not only piscine, but more nearly related to those of the most ancient Crossopterygian Ganoids than to those of any other fishes."[2]

[1]The Polypterini, Saurodipterini, Glyptodipterini, and Cœlacanthini are alone regarded as "Crossopterygii" by recent palichthyologists, the Ctenodipterini and Phaneropleurini being regarded as "Dipnoi."

[2]It may not be out of place for me to remark here that even earlier, in 1861, than the publication of Huxley's paper, I had recognized the common characters of the

Finally, in 1876, Huxley published, as "No. 1" of "Contributions to Morphology," a memoir "On *Ceratodus forsteri*, with observations on the classification of fishes." He still persisted in separating the recent Dipnoans from the extinct forms combined with the Crossopterygidæ, and contended that "even *Dipterus*, which approaches *Ceratodus* and *Lepidosiren* so closely in its dentition and in the form of its fins, is far more similar to *Polypterus* and *Amia* in other respects; and there is at present no reason to believe that any of the Crossopterygian Ganoids possessed other than a hyostylic skull, or differed from *Polypterus* in those respects in which *Polypterus* differs from the existing Dipnoi. All known Crossopterygians have jugular plates, of which there is no trace in the Dipnoi."

It will be thus seen that the suborder of Crossopterygidæ was really the result of a misunderstanding and included most Dipnoans (and to such extent was a synonym for that group) as well as the Crossopterygians of later authors. It was by no means the exact equivalent of Crossopterygians, and consequently the latter name can not be considered as a synonym of Crossopterygidæ or be replaced by it. Nevertheless the introduction of the so-called suborder was not only the expression of an advance in our knowledge of the system itself, but paved the way for future investigators.

I am even inclined to credit mainly to his sagacity the early appreciation of the affinity of the *Neoceratodus* of Australia to the mesozoic Ceratodontids with all the far-reaching consequences that appreciation involved. It was in 1870 that the living Ceratodontid was introduced to the scientific world as *Ceratodus forsteri*, and thus generically associated with the mesozoic fishes. How did Krefft (or Clarke) get the idea of this association of a living fish with some known only from fossil teeth referred by Agassiz to the same family, as the Cestraciont sharks? In 1861 Huxley published his Preliminary Essay upon the Systematic Arrangement of the Fishes of the Devonian Epoch, and therein suggested that *Ceratodus* was a Ctenodipterine fish and ranged it (with a mark of interrogation) by the side of *Dipterus*. He also drew "attention to the many and singular relations which obtain between that wonderful and apparently isolated fish, *Lepidosiren*," and the Ctenodipterine

Dipnoi and Polypteroids, and for that reason combined the two in the subclass Ganoidei. In a discussion of the subject (Cat. Fishes N. Am., p. 15), I remarked that "Milne-Edwards again urges as a previously neglected argument in favor of the amphibian nature of *Lepidosiren*, the opening of the ductus pneumaticus of the pulmonary sacs into the ventral face of the digestive canal. But we also find a similar arrangement in the species of the genus *Polypterus*, animals whose piscine character and affinities have never been called in question;" also, "It is a fact of no little interest that the *Polypteri*, which have an air bladder so similar to that of the *Lepidosirenes*, do also, of all known fishes, most resemble them in the form and development of the different elements of the brain." They differ, however, in cardiac and osteologic characters. I concluded that "as the Dipnoi agree in all other essential respects with the Ganoids, we will then at least provisionally consider them as belonging to the same great subclass."

fishes. (The exact truth was not discovered, but was approximated.) Is it not probable that this memoir was known to Clarke, who claimed to have suggested to Krefft the systematic relations of the newly discovered Australian Dipnoan? It was creditable to both Clarke and Krefft that they did recognize this relationship and profited by their bibliographical knowledge, but it is doubtful whether they would have been able to make the identification or appreciate the importance of the discovery had not Huxley partly prepared the way. By this discovery, our acquaintance with the ichthyic faunas of both the present and past was almost revolutionized.

VII.

To the casual observer none of the terrestrial backboned animals appear to be less related than birds and reptiles. As Huxley remarks, "to superficial observation no two groups of beings can appear to be more entirely dissimilar. - - - Placed side by side, a humming bird and a tortoise, an ostrich and a crocodile offer the strongest contrast, and a stork seems to have little but animality in common with the snake it swallows." A difference in habits appears to be associated with the difference in form. The activity and freedom of the bird contrasts with the lethargy and restriction in range of the tortoise—the warm body of the former with the cold mass of the latter. The birds are looked upon as inhabitants of the air, the reptiles as degraded to crawling on the earth. The popular conclusions were to a considerable extent adopted by the scientific, and for a long time the birds and mammals were associated together as "warm-blooded" in contradistinction to the reptiles and other vertebrates, which were designated as "cold-blooded." This classification was in vogue in England when Huxley reopened the question as to the relative affinities of the vertebrates, and in 1864 claimed that the classes of that division "are capable of being grouped into three provinces—(1) the Ichthyoids, comprising Fishes and Amphibia; - - - (2) the Sauroids, - - - comprising Reptiles and Birds; and (3) the Mammals.[1] - - - The Sauroids (afterwards called "Sauropsida") agree in having "a single occipital condyle, a complex mandibular ramus articulated to the skull by a quadrate bone, nucleated blood corpuscles," and thus differ from the mammals, which have "a well-developed basi-occipital - - -; a simple mandibular ramus articulated with the squamosal and not with the quadratum, with mammary glands and with red non-nucleated blood corpuscles."

In 1868 Huxley directed his inquiries "on the animals which are most nearly intermediate between birds and reptiles."[2]

The differences between the recent members of the two classes are

[1] Lectures on the Elements of Comparative Anatomy, 1864, page 74.

[2] Annals and Mag. Nat. Hist. (4.), Vol. II, pages 66–75.

indeed many. The question, then, was How far can this gap be filled up by a reference to the records of the life of past ages?

"The question resolves itself into two:

"(1) Are any fossil birds more reptilian than any of those now living?

"(2) Are any fossil reptiles more bird-like than living reptiles?

Both of these questions Huxley found "must be answered in the affirmative."

The remains of Archæopteryx found in the "lithographic slate of Solenhofen" furnished a bird with decided reptilian characters—so prominent, indeed, that some of the paleontologists of the period claimed that the animal was a reptile rather than a bird.

The remains of various Dinosaurians of Mesozoic times yielded reptiles with characteristics manifest only among the birds of the present epoch. Such characteristics were especially exemplified in details of structure of the hind limbs. One of the Dinosaurians—*Compsognathus*—was so much like a bird in the legs that "it is impossible to doubt that it hopped or walked, in an erect or semierect position, after the manner of a bird, to which its long neck, slight head, and small anterior limbs must have given it an extraordinary resemblance."

From the vantage ground of the present, with its increased stores, we may justify Huxley's "hope" that he had redeemed his "promise to show that in past times birds more like reptiles than any now living and reptiles more like birds than any now living did really exist." There is now even a tendency to regard the differences remaining between the birds and reptiles as of less than class value, and to combine both groups in one and the same class—Sauropsida. The first to propose such a union was Professor Cope, who had even to some extent anticipated Huxley in the recognition of the similarity between the Dinosaurians and birds. The fact that two such men independently arrived at similar conclusions is significant as evidence for their truth. But there is danger of pushing a truth to the extreme of itself deceiving. There is still a great gap between any known reptile and any known bird. Huxley concluded with the caution that, "as we possess hardly any knowledge of the terrestrial reptiles of [the Triassic] period, it may be regarded as certain that we have no knowledge of the animals which linked reptiles and birds together historically and genetically, and that the *Dinosauria*, with *Compsognathus*, *Archæopteryx*, and the struthious birds, only help us to form a reasonable conception of what these intermediate forms may have been." This cautious statement is as apt for the present time as that in which it was expressed."

VIII.

One of the most persistent prejudices that has influenced the progress of zoological taxonomy has been (perhaps still is) a belief in the importance of superficial adaptation of structure for life in the water contradistinguished from life on the land. This prejudice was long impressed

on ornithology. The birds with feet adapted for swimming by the development of webs between the toes or for wading by elongation of the legs were set apart from those fitted mainly for progress on land or through the air: in other words, from those having negative characters in such respects. The major subdivisions of those groups, too, were almost solely distinguished by superficial characters of little importance, such as the form of the bill, the character of the claws, and the combinations of toes. Variations in such trivial characters, which in other classes of vertebrates would be esteemed of little systematic value, were assigned ordinal rank. Comparative anatomy, too, was almost entirely neglected in the classification of birds; even most anatomists were content to limit their observations to simple irrelative details or to interject them into the framework of existing arrangements. Such was the state of ornithology in 1867 when Huxley published, in the Proceedings of the Zoological Society of London, a memoir "On the classification of birds, and on the taxonomic value of the modifications of certain of the cranial bones observable in that class." In this he discarded the characters generally used and allowed himself to be influenced by the modifications to be found in the skeleton without reference to the habits or habitats of the birds. He reduced the orders to three—the Saururæ (extinct), the Ratitæ, and the Carinatæ. The last, including almost all the living forms, were divided into primary groups defined by modifications of "the bones which enter into the formation of the palate." "Four different modes" were recognized and were "called, respectively, the *Dromæognathous*, *Schizognathous*, *Desmognathous*, and *Ægithognathous* arrangement" (p. 425). It was urged that "these cranial characters may safely be taken as indications of natural affinities" (p. 454), and Huxley proposed "to regard these divisions as suborders, and to name them *Dromæognathæ*, *Schizognathæ*, *Desmognathæ*, and *Ægithognathæ* (p. 456). The last three suborders were divided into groups with the termination -morphæ, as Ætomorphæ (Raptores), Psittacomorphæ (Psittaci), etc., not taxonomically designated, but essentially equivalent to "superfamilies." The Ægithognathous "Coracomorphæ" corresponded with the "Passeres" as limited by recent naturalists, and Huxley was "disposed" to divide it "into two primary groups, one containing *Menura*, and the other all the other genera." How the immense aggregate represented by all the other genera were to be subdivided Huxley did not venture to decide, but he leaves the impression that he had little respect for the numerous "families" which had been recognized by most ornithologists.

The value of this work consisted chiefly in disturbing the old classifications and calling attention to the proper method of investigation. Much of it, nevertheless, appears to have been of permanent value, and most of the superfamilies at least have been recognized as natural assemblages, although still generally given ordinal or subordinal rank

and endowed with older names. The memoir at least gave an impulse in the right direction—morphological as opposed to teleological—and has incited to many elaborate investigations to the great advantage of ornithology.

IX.

Much doubt had existed respecting the nature of the non-mammalian ancestors of the mammals. It was supposed by some that they must have been reptiles related to the Dinosaurians, but the specialized characteristics and high development of that type forbade the belief that they were in the direct line of descent. Of course the birds which agreed with the mammals in the possession of a quadrilocular heart, complete circulation, and warm blood must even more positively than the Dinosaurians be excluded from the line of descent. The problem of what was the genealogy of the highest class of animals was at last attacked by Huxley. In several memoirs,[1] published in 1876, 1879,[2] and 1880,[3] he examined the evidence and formulated his conclusions. Those conclusions were expressed in the following terms:

"Our existing classifications have no place for [the] submammalian stage of evolution (already indicated by Haeckel under the name of *Promammale*). It would be separated from the Sauropsida by its two condyles, and by the retention of the left as the principal aortic arch; while it would probably be no less differentiated from the Amphibia by the presence of an amnion and the absence of branchiæ at any period of life. I propose to term the representatives of this stage *Hypotheria;* and I do not doubt that when we have a fuller knowledge of the terrestrial vertebrata of the later palæozoic epochs, forms belonging to this stage will be found among them. Now, if we take away from the Hypotheria the amnion and the corpus callosum, and add the functional branchiæ—the existence of which in the ancestors of the mammalia is as clearly indicated by their visceral arches and clefts as the existence of complete clavicles in the ancestral Canidæ is indicated by their vestiges in the dog—the Hypotheria, thus reduced, at once take their place among the Amphibia, for the presence of branchiæ implies that of an incompletely divided ventricle and of numerous aortic arches, such as exist in the mammalian embryo, but are more or less completely suppressed in the course of its development.

"Thus I regard the amphibian type as the representative of the next lower stage of vertebrate evolution; and it is extremely interesting to

[1] On the evidences as to the origin of existing vertebrate animals. (Nature, Vol. XIII, pp. 388, 389, 410–412, 429, 430, 467–469, 514–516; Vol. XIV, pp. 33, 34.

[2] On the characters of the pelvis in the mammalia, and the conclusions respecting the origin of mammals which may be based on them. (Proc. Royal Soc., Vol. XXVIII, pp. 162, 163; Nature, Vol. XX, pp. 22–24.)

[3] On the application of the laws of evolution to the arrangement of the vertebrata, and more particularly of the mammalia. (Proc. Zool. Soc., 1880, pp. 649–662; Nature, Vol. XXIII, pp. 203, 204, 227–231.)

observe that even the existing Amphibia present us with almost every degree of modification of the type, from such forms as the oviparous, branchiate, small-lunged *Siredon* and *Menobranchus*, which stand in the same relation to it as *Gymnura* to the Eutheria, to the exclusively air-breathing Salamanders and frogs, in which the period of intraovular development, either within the uterus itself or in special receptacles, may be as much prolonged as it is in the mammalia.

"A careful study, on full materials, of the development of the young of such forms as *Hylodes* will probably throw great light on the nature of the changes which ended in the suppression of the branchiæ and the development of the amnion and of the extra-abdominal part of the allantois in the fœtus of the higher vertebrata."

During the intervening years no discoveries of fossil forms substantiating these inferences have been discovered. Among the ancient vertebrates now known none appear to be more nearly allied to the mammals than certain Permian animals representing a special order named by Cope Theromorpha or (later) Theromora. As early as 1878 "the order Theromorpha was regarded by Professor Cope as approximating the mammalia more closely than any other division of reptilia, and as probably the ancestral group from which the latter were derived."[1] These views were subsequently developed in greater detail,[2] and appear to be entitled to much consideration. In this connection it may be added that the difference between Huxley and Cope is less than the terms in which they have been stated might seem to indicate. The gap between primitive amphibians and reptiles is by no means as great as between the modern types, and it may be doubted whether the ancestors of the mammalian stock were members of the specialized order defined as Theromorpha. Neither of the philosophers may be far out of the way.

X.

Among the most important results of Huxley's investigations were the discovery and approximately correct recognition of the nature of the "peculiar gelatinous bodies" found in all the seas, whether extra-tropical or tropical, through which the *Rattlesnake* sailed, and which were named *Thalassicola*, precursors of radiolarian hosts afterwards to be brought to light, and the perception of the comparative affinities of the southern forms of astacoidean crustaceans and their contrast as a group with the forms of the Northern Hemisphere. I must resist the temptation to further enumerate the great naturalist's discoveries and generalizations.

A few words on the nature of his work may be desirable. And here it may be admitted that Huxley was rather a morphologist in a narrow

[1] The Theromorphous Reptilia. (Am. Nat., Vol. XII, pp. 829, 830, 1878.)

[2] The relations of the theromorphous reptiles and the monotreme mammalia. (Proc. Am. Assoc. Adv. Sc., Vol. XXXIII, pp. 471–482, 1 plate, 1885.)

sense, or anatomist rather than a systematist of greatly superior excellence. Unquestionably he did much excellent work in systematic zoology, but the direct subject of investigation was perhaps treated from too special a standpoint, and sometimes without an attempt to coordinate it with the results in other fields, or to measure by some given standard. He was indeed a great artist, but he used his powers chiefly to sketch the outlines of a picture of nature. This was done with the bold and vigorous hand of a master, but his productions were deficient in details and finish and were sometimes imperfect on account of inattention to perspective and perhaps deliberate neglect of the niceties of nomenclature. (And lest I may be misunderstood, let me here explain that by systematic zoology I mean the expression of all the facts of structure in a form to best represent the values of the differences as well as resemblances of all the constituents and parts of the entire organization, from the cells to the perfected organs and the body as a whole.) For example, he separated amphibians from reptiles and combined them with fishes, and yet under the last name comprised the Leptocardians and Marsipobranchs, and to his influence is doubtless due to a large extent the persistence of English (but not American) naturalists in a combination which is elsewhere regarded as contradicted by all sound morphological doctrine.[1] The value of the characters distinctive of the Rhynchocephalian reptiles and their consequent significance for taxonomy and paleontology were also denied by him. Nevertheless, even his negative position was of use in that it incited investigation. The numerous memoirs on the anatomy and characteristics of various groups of animals, too, were always replete with new facts and the hints were almost always sagacious, even if not always in exactly the right direction.

XI.

While the contest between the old and new schools of biological philosophy was at its height, the former was almost entirely supported by the religious element, and bitter were the invectives against evolution. The opposition was almost solely based on the ground that the doctrine was in opposition to revealed religion. The naturally combative disposition of Huxley was much aroused by this opposition, and the antagonism early engendered was kept aglow during his entire life. Meanwhile it had been discovered by many of the more sagacious and learned clergymen that there was no real antagonism between the scriptural account of creation and evolution, but that the two could be perfectly reconciled. The reconciliation had been effected between Genesis and astronomy and between Genesis and geology, and was continued on the same lines for Genesis and evolution. But Huxley

[1] The great English morphologists (such as Balfour and Ray Lankester), Huxley's own successor in the Royal College of Science, Professor Howes, and A. Smith Woodward among systematic ichthyologists have recognized the heterogeneity of the old class of fishes.

would have none of it. He gave expression to his convictions in the following words:

"For more than a thousand years, the great majority of the most highly civilized and instructed nations in the world have confidently believed and passionately maintained that certain writings, which they entitle sacred, occupy a unique position in literature, in that they possess an authority, different in kind, and immeasurably superior in weight, to that of all other books. Age after age, they have held it to be an indisputable truth that, whoever may be ostensible writers of the Jewish, Christian, and Mohomedan Scriptures, God Himself is their real author; and, since one of the attributes of the Deity excludes the possibility of error and—at least in relation to this particular matter—of willful deception, they have drawn the logical conclusion that the denier of the accuracy of any statement, the questioner of the binding force of any command, to be found in these documents is not merely a fool, but a blasphemer. From the point of view of mere reason he grossly blunders; from that of religion he grievously sins.

"But if this dogma of Rabbinical invention is well founded; if, for example, every word in our Bible has been dictated by the Deity, or even if it be held to be the Divine purpose that every proposition should be understood by the hearer or reader in the plain sense of the words employed (and it seems impossible to reconcile the Divine attribute of truthfulness with any other intention), a serious strain upon faith must arise. Moreover, experience has proved that the severity of this strain tends to increase, and in an even more rapid ratio, with the growth in intelligence of mankind and with the enlargement of the sphere of assured knowledge among them.

"It is becoming, if it has not become, impossible for men of clear intellect and adequate instruction to believe, and it has ceased, or is ceasing, to be possible for such men honestly to say they believe that the universe came into being in the fashion described in the first chapter of Genesis; or to accept, as a literal truth, the story of the making of woman with the account of the catastrophe which followed hard upon it, in the second chapter; or to admit that the earth was repeopled with terrestrial inhabitants by migration from Armenia to Kurdistan, little more than four thousand years ago, which is implied in the eighth chapter; or, finally, to shape their conduct in accordance with the conviction that the world is haunted by innumerable demons, who take possession of men and may be driven out of them by exorcistic adjurations, which pervades the Gospels."

So far even Huxley was not in disagreement with some of the most eminent and learned of theologians. Those of you who are interested will be able to recall utterances of enlightened clergymen which would differ from Huxley's only in the absence of the leaven of sarcasm that permeates his lines. At a late congress of the Church of England, held at Norwich, the reverend Canon and Professor Bonney gave voice to words that convey the same ideas as Huxley's.

"I can not deny," he said, "that the increase of scientific knowledge has deprived parts of the earlier books of the Bible of the historical value which was generally attributed to them by our forefathers. The story of the creation in Genesis, unless we play fast and loose either with words or with science, can not be brought into harmony with what we have learned from geology. Its ethnological statements are imperfect, if not sometimes inaccurate. The stories of the flood and of the Tower of Babel are incredible in their present form. Some historical element may underlie many of the traditions in the first eleven chapters of that book, but this we can not hope to recover."

But Huxley was not content to deny any authority to the Scriptural basis of most of the religions of Europe and America. He denied that there was any means of knowing what the future had in store. He did not deny that there was a heaven or a hell; he did not deny that in a future world man might continue in a sublimated state, and might be punished for his misdeeds or rewarded for the good deeds he had performed and for good thoughts on earth. He did not venture to express any opinion on the subject for the reason that he had no data to base an opinion upon. He called himself an agnostic and the attitude he assumed was agnosticism.

This term agnostic, we are told by Mr. R. H. Hutton, was suggested by Professor Huxley at a party held previous to the formation of the now defunct Metaphysical Society, at Mr. James Knowles's house on Clapham Common, one evening in 1869, and was suggested by St. Paul's mention of the altar to the unknown God—'Αγνώστῳ θεῷ.

But Huxley has explained that he assumed this term in contradistinction to the gnostic of old. The gnostic claimed to know what in the nature of things is unknowable, and as Huxley found himself with an exactly opposite mental status, he coined a word to express that antithetical state—agnostic.

I have done all I conceive to be necessary in giving this statement of Huxley's attitude. Whether he was right or wrong, each one must judge for himself or herself. Believing as he did, on a bed of prolonged illness he resignedly awaited the inevitable, and desired that his sentiments reflected in verse by his wife should be engraved on his tomb.

"And if there be no meeting past the grave,
If all is darkness, silence, yet 'tis rest.
Be not afraid, ye waiting hearts that weep,
For God 'still giveth his beloved sleep,'
And if an endless sleep he wills—so best."